Renewable and Sustainable Energy Reviews 33 (2014) 96–101

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Are fluctuations in coal consumption per capita temporary? Evidence from developed and developing economies

Muhammad Shahbaz [a,1], Aviral Kumar Tiwari [b], Farooq Ahmed Jam [c], Ilhan Ozturk [d,*]

[a] Department of Management Sciences, COMSATS Institute of Information Technology, Lahore, Pakistan
[b] Faculty of Management, ICFAI University Tripura, Kamalghat, Sadar 799210, Tripura, India
[c] Institute of Graduate Studies, University of Malaya, Kuala Lumpur, Malaysia
[d] Faculty of Economics and Administrative Sciences, Cag University, 33800 Mersin, Turkey

ARTICLE INFO

Article history:
Received 5 September 2013
Received in revised form
2 January 2014
Accepted 31 January 2014
Available online 21 February 2014

Keywords:
Coal consumption
Transitory
Stationarity
Permanent
Unit root

ABSTRACT

This paper investigates the unit root properties of coal consumption per capita for the 47 developed and developing countries for 1965–2010 period. To examine the stationary properties of coal consumption per capita, Lagrange multiplier (LM) unit root test with one break and two breaks Crash model has been utilized. According to empirical results, the coal consumption is stationary in almost all the countries analyzed. Thus, if the coal consumption is mean (or trend) reverting, then it follows that the series will return to its mean value (or trend path) and it might be possible to forecast future movements in the coal consumption based on past behaviors of the series. For the policy makers, it is not necessary to pay attention to coal consumption excepting for Indian and Italian. However, for the researchers it is important to take into account the stationarity property of coal consumption and also structural breaks (should be modeled) in their future studies.

Contents

1. Introduction

Human civilization is basically a main determinant of energy consumption. That's why energy demand has strong implications for human civilization's social–economic–political sphere. The empirical investigation of unit root properties of energy consumption is very important because it not only helps us in designing the relationship between economic growth and energy consumption but also energy-environment relationship. It is warned by International Energy Agency (IEA) that rising energy demand due to economic growth, industrialization and urbanisation increases CO_2 emissions every year rapidly and all allowable CO_2 emissions should be locked by utilizing the existing energy-efficient infrastructure (IEA, [1]). Energy sources such renewable and non-renewable play important role in stimulating economic activity in an economy (Shahbaz et al. [2], Zeshan and Ahmad, [3]). In renewable energy, sunlight, wind, tides, plants and geothermal heat are major sources of energy (IEA, [1]). A natural process is involved to derive renewable energy which is replenished consistently. Renewable energy is directly derived from the sun, heat generated deep within the earth as well as electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and bio-fuels and hydrogen are also considered as renewable resources. In 2012, growth rate of wind power with worldwide installed capacity of 282, 482 MW. This source of energy is used in

* Corresponding author. Tel./fax: +90 324 6514828.
E-mail addresses: shahbazmohd@live.com (M. Shahbaz), aviral.eco@gmail.com (A.K. Tiwari), jam_farooq@yahoo.co.uk (F.A. Jam), ilhanozturk@cag.edu.tr (I. Ozturk).
[1] Fax: +92 42 99203100; mob.: +92334 3664 657.

http://dx.doi.org/10.1016/j.rser.2014.01.086
1364-0321

Europe, Asia as well as in the United States. The photovoltaic (PV) capacity worldwide was 100,000 MW as well as PV power stations are wised operated in Germany and Italy. The 354 MW SEGS power plant has been working in the Mojave Desert and solar thermal power stations are also operating in the USA and Spain. Brail uses ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel which is the largest renewable energy program in the world. The USA also uses this source of renewable energy to meet its domestic demand. Biomass is another source of renewable energy which is used by almost 44 million household in household-scale digesters for lighting and/or cooking. Hydropower is generated from water which is the most abundant energy source on globe but less than natural gas reserves. The production hydroelectricity was 3500 billion kilowatt-hours in 2011 and production would be doubled by 2010 (IEA, [1]). Geothermal energy is internal heat of earth and it is used for heating and cooling buildings. Geothermal installed capacity is 11,224 MW in 2012 and electricity generation from geothermal sources is double times greater than electricity generated from solar energy sources. Ocean's tides from the gravitational pull of the moon and the sun upon the earth is also termed as renewable energy.

Non-renewable energy is comprised of coal, crude oil, natural gas and uranium which are mainly made up of carbon. World oil consumption was 87.421 million barrels per day in 2000 which has been risen to 88.9 million barrels per day but petroleum demand has been declined due to hike in petroleum prices and financial crisis in USA and Europe in 2012 (IEA, [1]). Petroleum demand has increased to 4.4 million barrels per day in Asian region but rapid industrial growth in China and India has increased 2.8 million barrels per day and 800,000 bbl/d, respectively. Globally, demand for natural gas consumption rose to 113 Tcf (Trillion cubic feet) in 2010 from 53 Tcf in 1980 [1]. In North America, gas demand was 29% in 1980 and declined to 25% in 2010. Natural gas consumption was increased more than tenfold from 1.3 Tcf in 1980 to 13.2 Tcf in 2010 in the Middle East due rapid economic growth. In Asian region, natural gas demand has increased more than eight-fold from 2.2 Tcf to 19.2 Tcf for last three decades. Asian natural gas demand approached the level of Europe and the Former Soviet Union in 2010. Globally, coal demand continued to grow in 2011. The growth in coal consumption is due rapid use of coal. In 2011, global coal consumption was 3724.3 million tons of oil equivalents (mtoe) which was 5.4% higher than coal demand in 2010. A 8.4% equalent to 2625.7 mtoe coal was consumed by OECD countries in 2011 which is 70.5% of global coal consumption. In Asia, growth in coal consumption was more than 9% in 2011 in China and India due rapid industrialization and hence economic growth [1]. China's coal consumption had grown by 325 million tons equalent to 87% of global coal consumption in 2011 and it was 2.3 billion tons i.e. 82% of global coal consumption in 2000. In 2012, China's coal demand accounts for 47% of world coal consumption.

Non-renewable energy sources such as coal, natural gas and oil i.e. fossil fuels are cheap and abundantly available. Coal is considered second source of energy after oil and source of electricity generation in 21 century. This provides a rational for researchers to investigate the stationarity properties of coal consumption per capita using data of 47 developed and developing countries. We have applied Lagrange multiplier (LM) structural break unit root test. It is very important for policy makers to know whether fluctuations in coal consumption are transitory or permanent from various aspects. First, if coal consumption is to be found stationary then fluctuations in energy consumption are transitory. If coal consumption follows stationary process then long run energy policies would not be effective. Coal consumption tends to return to its original symmetric path following shocks in energy markets. In such an environment, governing bodies should not implement redundant goals. Fluctuations in coal consumption are considered permanent if coal consumption has unit root problem. In such environment, coal consumption is consistent stable with path dependency. Path dependency of coal consumption implies that world energy markets innovation would affect permanent impacts. Furthermore, the degree to which the coal sector is linked with other sectors of the economy is also of significance as permanent shocks to coal consumption may well be transmitted to other sectors of the economy as well as to macroeconomic aggregates.

Third, the distinction between temporary and permanent shocks to coal consumption influences the modeling of energy demand and forecasting. Forecasts of coal consumption play a vital role in formulating energy policies. Safe and efficient energy supply for economic growth can be possible after knowing the reliable forecasts of energy consumption in the future. If coal consumption is stationary, then the past behavior of coal consumption serves a role in the generation of forecasts. On the other hand, if coal consumption is non-stationary, then the past behavior of coal consumption serves little or no use in forecasting. Fourth, the distinction between transitory or permanent shocks in coal consumption is very important to model the relationship between energy (coal) consumption and economic growth.

Table 1 provides summary of existing studies investigating whether fluctuations in energy consumption are permanent or transitory. These studies have applied various approaches to test the stationarity properties of energy consumption and provided ambiguous results.[2] Recently, Apergis et al. [5] investigated the unit root properties of coal consumption in 50 US states using several panel unit root tests [6–8]. Our study contributes in existing literature by investigating the unit root properties of coal consumption by applying Lee and Strazicich [9,10] unit root test with one and two structural breaks stemming in the series. Our results are more reliable and efficient due to superiority of Lee and Strazicich [9,10] unit root test over traditional unit root tests.

The aim of our study is to investigate the stationarity properties of coal consumption using data of 47 countries for 1965–2010 period.[3] To examine the stationary properties of coal consumption per capita, Lagrange multiplier (LM) unit root test with one break and two breaks Crash model and one and two break trend models have been employed. We have provided the trend of coal consumption in sample countries (see Fig. 1).

2. Methodology and data

There are various unit root tests available to test the stationarity properties of macroeconomic variables. These unit root tests are like ADF by Dickey and Fuller, [36]; PP by Phillips and Perron [37] and Perron [38]. These tests found to give misleading results (i.e. biased towards the non-rejection of null hypothesis when structural breaks are present in the data series). Following Perron [39] and Zivot and Andrews [40] proposed to determine the structural breaks stemming in the series endogenously. Lumsdaine and Papel [41] pointed out the importance of unit root test with two structural breaks in the series by modifying Zivot and Andrews [40] unit root test. These unit root tests were criticized by statisticians due to the usage of structural breaks in their null hypothesis. These tests do not consider the presence of structural break in the null hypothesis and suggest that variable is found to be stationary in the presence of structural break. Therefore, in the present study we have adopted Lee and Strazicich [9,10] test of unit root that allows us to test for at most two endogenous breaks and uses the Lagrange multiplier (LM) test statistics.[4] Let us consider the following data generating process (DGP):

$$y = \delta Z_t + e_{t,}, \quad e_t = \beta e_{t-1} + \varepsilon_t \tag{1}$$

[2] See the study of Smyth [4] for a extensive literature survey on the integration properties of energy consumption variables.

[3] Availability of data has restricted our analysis to 47 countries.

[4] Lee and Strazicich [9,10] unit root test avoids all issues discussed above.

Table 1
Survey of literature for stationarity properties.

Authors	Time period	Unit root test	Conclusion
Narayan and Smyth [11]	1954–2003	Zivot and Andrews [40] test	Unit root exists
Al-Iriani [12]	1979–2000	Univariate and IPS panel tests	Stationarity is found
Soytas and Sari [13]	1971–2000	Carrion-i-Silvestre multiple Test [8]	Stationarity is found
Zachariadis and Pashourtidou [14]	1973–2008	LM structural break test	Stationarity is found
Narayan and Smyth [15]	1971–2003	Panel seemingly unrelated regressions ADF	Unit root exists
Chen and Lee [16]	1973–2008	Long memory test	Miscellaneous results
Narayan et al. [17]	1973–2007	Lee and Strazicich [10] two Structural break Test	Stationarity is found
Hsu et al. [18]	1971–2003	Panl unit root test	Mixed results
Mishra et al. [19]	1980–2005	LLC, IPS and Maddalae Wu panel tests and CIPS test	Miscellaneous results
Narayan et al. [20]	1973–2007	Lee and Strazicich [10] univariate unit root tests with up to two structural breaks	Stationarity is found
Apergis et al. [5]	1982–2007	LM structural break test	Stationarity is found
Ozturk and Aslan [21]	1970–2006	Lee and Strazicich [10] two Structural break Test	Stationarity is found
Kum [22]	1971–2007	Lee and Strazicich [9,10] one structural break test	Stationarity is found
Kula et al. [23]	1960–2005	LM structural break test	Stationarity is found
Apergis and Tsoumas [24]	1989–2009	Fractional integration with structural breaks	Mixed results
Maslyuk and Dharmaratna [25]	1966–2009	Zivot and Andrews [40] and Clemente et al. [26] univariate unit root tests with structural breaks	Mixed evidence of stationarity
Congregado et al. [27]	1973–2010	Non-linear specification of an unobserved components model	Evidence of persistence
Shahbaz et al. [28]	1971–2010	Lee and Strazicich [9,10] univariate unit root tests with up to two structural breaks	Stationarity is found
Lean and Smyth [29]	1978–2010	Lee and Strazicich [9,10] univariate unit root tests with up to two structural breaks	Stationarity is found
Bolat et al. [30]	1960–2009	KPSS unit root test	Stationarity is found
Bolat et al. [31]	1971–2010	LM test with two breaks	Stationarity is found
Barros et al. [32]	1973–2010	LM test with two breaks	Unit root exists
Meng et al. [33]	1960–2010	LM and RALS-LM unit root tests	Stationarity is found
Barros et al. [34]	1994–2011	LM test with two breaks	Evidence of persistence
Ozcan [35]	1980–2009	Lee and Strazicich [9,10] and Im et al. [42])	Stationarity is found

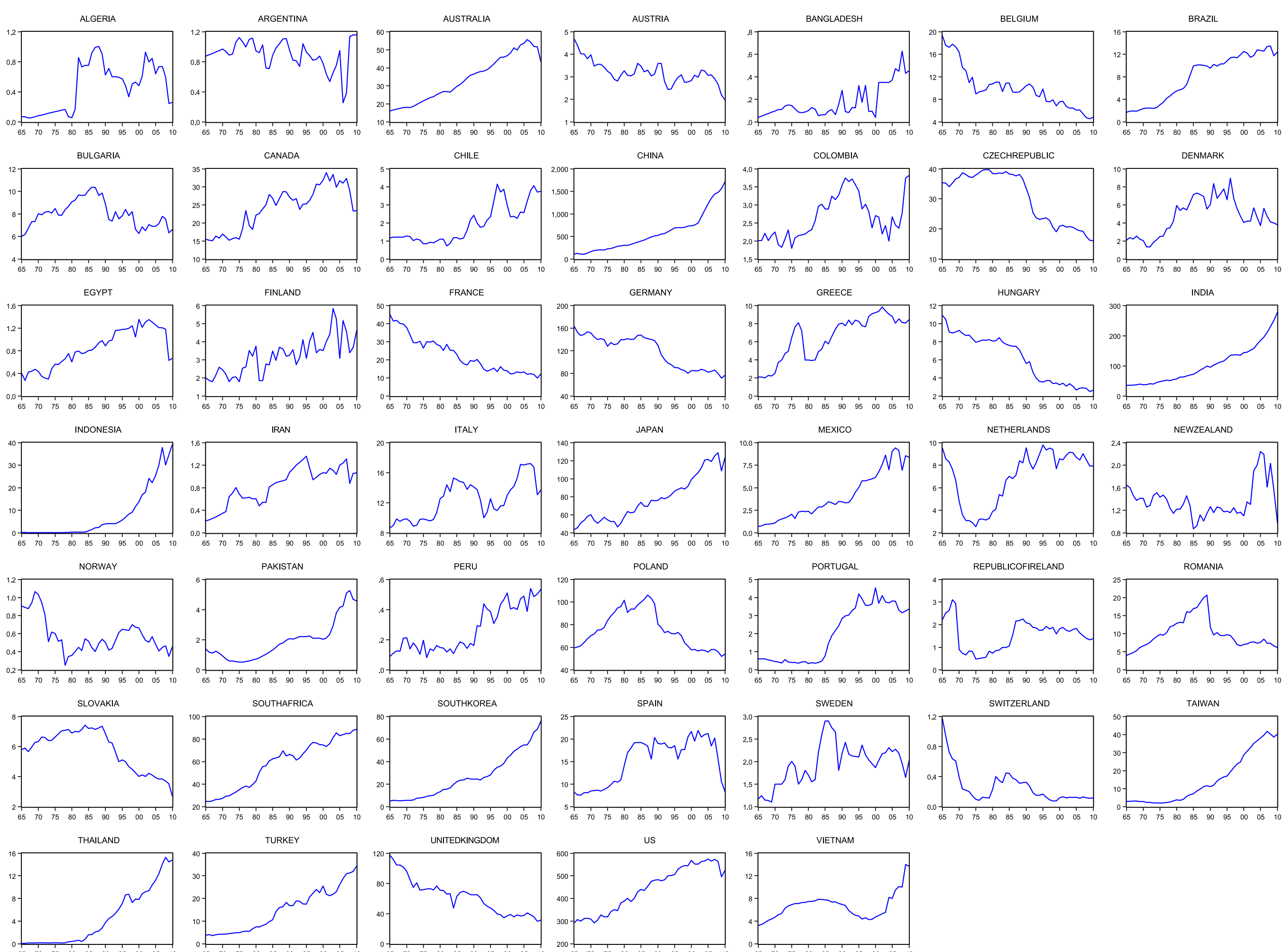


Fig. 1. Coal consumption in sample countries.

where Z_t is a vector of exogenous variables, δ is a vector of parameters and ε_t is a white noise process, such that $\varepsilon_t \sim NIID(0, \sigma^2)$. First we will consider the case when break there is evidence of one structural break. The Crash model that allows shift in level only is described by $Z_t = [1, t, D_t]'$, and the break model that allows for changes in both level and trend is described as $Z_t = [1, t, D_t DT_t]'$, where D_t and DT_t are two dummies defined as:

$D_t = 1$, if $t \geq T_B + 1 = 0$, otherwise and $DT_t = t - T_B$, if $t \geq T_B + 1 = 0$, otherwise where T_B is the time period of the break date.

Next, let us consider the framework that allows for two structural breaks. The crash model that considers two shifts in level only is described by $Z_t = [1, t, D_{1t}, D_{2t}]'$, and the break model that allows for two changes in both level and trend is described as $Z_t = [1, t, D_{1t} DT_{1t} D_{2t} DT_{2t}]'$, where D_{jt} and DT_{jt} for $j = 1, 2$ are appropriate dummies defined as above, viz., $D_{jt} = 1$, if $t \geq T_{Bj} + 1 = 0$, otherwise and $DT_{tj} = t - T_{Bj}$, if $t \geq T_{Bj} + 1 = 0$, otherwise where T_{Bj} is the jth break date.

The main advantage of Lee and Strazicich [9,10] approach to unit root test is that it allows for breaks under the null ($\beta = 1$) and alternative ($\beta < 1$) in the DGP given in Eq. (1). This method uses the following regression to obtain the LM unit root test statistics.

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta \tilde{S}_{t-j} + u_t. \quad (2)$$

where $\tilde{S}_t = y_t - \tilde{\Psi}_t - Z_t \tilde{\delta}, t = 2, \ldots, T$; $\tilde{\delta}$ denotes the regression coefficient of Δy_t on ΔZ_t and $\tilde{\Psi}_t = y_t - Z_1 \tilde{\delta}$, y_1 and Z_1 being first observations of y_t and Z_t respectively. The lagged term $\Delta \tilde{S}_{t-j}$ are included to correct for likely serial correlation in errors. Using the above equation, the null hypothesis of unit root test ($\phi = 0$) is tested by the LM t-statistics. The location of the structural break or structural breaks is determined by selecting all possible breaks for the minimum t-statistic as follows:

$$\ln f \tilde{\tau}(\bar{\lambda}_i) = \ln_{\lambda} f \tilde{\tau}(\lambda), \text{where } \lambda = T_B / T$$

The search is carried out over the trimming region (0.15T, 0.85T), where T is sample size and T_B denotes date of structural break. We determined the breaks where the endogenous two-break LM t-test statistic is at a minimum. The critical values are tabulated in Lee and Strazicich [9,10] for the two-break and one-break cases respectively.

The data on coal consumption per capita (kW h) has been obtained from World Bank's World Development Indicators (WDI-CD, 2012). We have used data of 47 developed and developing countries over the period of 1965–2010. The countries in sample are US, Canada, Mexico, Argentina, Brazil, Chile, Colombia, Peru, Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Rep. of Ireland, Italy, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom, Iran, Algeria, Egypt, South Africa, Australia, Bangladesh, China, India, Indonesia, Japan, New Zeeland, Pakistan, South Korea, Taiwan, Thailand and Vietnam. These countries are selected according to data availability.

3. Results and interpretations

Table 2 reports the results of LM unit root test when presence of one structural break is taken into account. We set maximum lag 4 because of small sample and last lag was based on its significance level at 10%. We analyzed two models for such case-namely when one structural break is present is constant term (we call is Crash model of one break; formally known as model A) and when structural break is present in constant and trend both (we call it Trend break model of one break; formally known as model B).

Table 2
LM unit root test with one structural break.

No.	Countries	Model 1: Crash model			Model 2: trend break model		
		T_{B1}	t. Statistics	K	T_{B1}	t. Statistics	K
1	US	1983	−1.5674	0	1997	−3.0876	0
2	Canada	1979	−2.1815	0	1978	−2.9493	0
3	Mexico	1987	−3.4180	0	1980	−3.9741**	4
4	Argentina	2006	−4.8767**	0	2004	−6.1110*	1
5	Brazil	1990	−1.4996	1	1982	−3.4205***	1
6	Chile	1981	−2.0984	1	1984	−3.5811**	1
7	Colombia	1994	−2.9846	0	2006	−2.9949	4
8	Peru	1990	−5.2005*	0	1990	−5.2882*	0
9	Austria	1994	−1.7174	0	2001	−3.8793**	1
10	Belgium	1983	−2.4154	0	1978	−3.7393**	0
11	Bulgaria	1990	−1.3634	0	1989	−4.1231**	3
12	Czech Republic	2000	−1.6578	1	1981	−2.9088	1
13	Denmark	1979	−1.6984	0	1979	−2.8853	0
14	Finland	2003	−5.5426*	0	2002	−5.4445*	0
15	France	1985	−4.7037**	0	1984	−4.5581*	0
16	Germany	1990	−1.5602	0	1990	−1.9120	0
17	Greece	1979	−3.1506	1	1980	−3.4245***	1
18	Hungary	1991	−2.1035	0	1991	−2.9405	0
19	Rep. of Ireland	1985	−1.8254	0	1986	−4.3111**	0
20	Italy	1979	−2.0087	0	1980	−2.1740	0
21	The Netherlands	1974	−0.7786	0	1979	−1.9524	0
22	Norway	1992	−2.6212	0	1981	−3.2991***	0
23	Poland	1980	−0.8164	1	1988	−2.5766	0
24	Portugal	1984	−1.0067	0	1985	−2.1118	0
25	Romania	1997	−0.4939	0	1990	−2.5658	0
26	Slovakia	1992	−0.5027	0	1982	−2.9184	0
27	Spain	1988	−1.6310	1	1978	−2.3100	0
28	Sweden	1991	−2.8598	0	1988	−4.4682*	1
29	Switzerland	1980	−3.2231	4	1985	−3.2659***	3
30	Turkey	1985	−1.7955	0	1985	−2.4967	0
31	United Kingdom	1985	−3.0394	0	1985	−3.2927**	0
32	Iran	1996	−1.7731	0	1975	−2.4522	0
33	Algeria	1981	−3.0425	0	1983	−4.3583*	1
34	Egypt	1980	−1.6230	0	2000	−3.3609***	0
35	South Africa	1980	−1.5316	0	1983	−3.6169**	1
36	Australia	1981	−1.1644	2	2002	−4.9777*	2
37	Bangladesh	1982	−4.3414**	0	1998	−4.6971*	0
38	China	1974	−3.4671***	1	1997	−5.2671*	1
39	India	1986	−2.0012	0	1974	−2.2247	0
40	Indonesia	1975	−0.9690	0	1985	−2.2696	0
41	Japan	1974	−3.7025***	0	2002	−3.7170**	0
42	New Zeeland	2000	−2.0007	0	2001	−5.4293*	3
43	Pakistan	1979	−2.0892	1	1984	−4.1285**	3
44	South Korea	1978	−2.8984	3	1978	−2.7116	3
45	Taiwan	1983	−1.8484	3	1981	−3.0162	1
46	Thailand	1984	−1.5655	0	1984	−3.4312***	3
47	Vietnam	2006	−3.3912***	3	2006	−3.2916***	3

Note: This table presents Results for univariate LM unit root test with two structural breaks in intercept/constant and trend both. T_{B1} and T_{B2} are the dates of the structural breaks; k is the lag length that is the optimal number of lagged first differenced terms included in the unit root test to correct for serial correlation. The 1%, 5% and 10% critical values for the minimum LM test with one break are −4.239, −3.566 and −3.211, respectively.

* Denote statistical significance at the 10% level.

** Denote statistical significance at the 5% level.

*** Denote statistical significance at the 1% level.

It is evident from Table 2 that when model A (i.e. Crash model of one break) is analyzed we found that only for 8 countries out of 47 null hypothesis of unit root is rejected. Those countries are: Argentina, Bangladesh, China, Finland, France, Japan, Peru and Vietnam. However, when we analyzed Trend break model of one break we found that for 27 countries out of 47, the null hypothesis of unit root was rejected. Since, there is possibility that countries might have experienced a number of shocks which might have caused breaks in the data. Therefore; we analyzed the situation for two structural break models. Results of unit root that incorporates structural breaks in level and/or trend are presented in following Table 3.

Table 3
LM unit root test with two structural breaks.

No	Countries	Model 1: Crash model				Model 2: trend break model			
		T_{B1}	T_{B2}	*t*. Statistics	*K*	T_{B1}	T_{B2}	*t*. Statistics	*K*
1	US	1978	1983	−1.7637	0	1979	1998	−4.5634*	0
2	Canada	1979	2003	−2.3553	0	1980	2004	−3.7784***	0
3	Mexico	1976	1980	−4.3376**	4	1974	1994	−5.2818*	0
4	Argentina	2000	2006	−5.3911*	0	1998	2004	−7.0429*	1
5	Brazil	1986	1990	−1.5979	1	1976	1983	−5.8129*	1
6	Chile	1987	1995	−2.4001	0	1982	2000	−5.2064*	1
7	Colombia	1999	2006	−3.6051***	4	1990	2002	−4.5101**	0
8	Peru	1981	1990	−5.5277*	0	1973	1990	−6.5053*	0
9	Austria	1983	1994	−1.8558	0	1979	2000	−5.0325*	1
10	Belgium	1983	1989	−2.7375	0	1973	1991	−5.4797*	3
11	Bulgaria	1990	1998	−1.9317	0	1988	2004	−5.3188*	3
12	Czech Republic	1989	2000	−1.7277	1	1989	2001	−5.7080*	1
13	Denmark	1979	1996	−1.9341	0	1973	1985	−4.3595**	0
14	Finland	1981	2003	−6.1059*	0	1979	1985	−6.5940*	3
15	France	1985	1993	−5.0846**	0	1982	2002	−5.3515*	2
16	Germany	1978	1990	−1.7369	0	1978	1989	−3.6139***	4
17	Greece	1979	1984	−3.2920	1	1980	1992	−4.1574**	1
18	Hungary	1995	2004	−2.3940	4	1980	1992	−4.7248*	0
19	Rep. of Ireland	1978	1985	−2.0481	0	1974	1986	−12.2736*	2
20	Italy	1979	1991	−2.2529	0	1981	1999	−3.0423	0
21	The Netherlands	1974	1978	−0.8062	0	1980	1990	−5.9684*	4
22	Norway	1987	1992	−2.9694	0	1976	1994	−4.5084**	0
23	Poland	1980	1990	−1.2578	1	1983	2000	−4.7584*	2
24	Portugal	1973	2001	−1.6598	1	1978	1989	−5.5833*	3
25	Romania	1990	1997	−0.5520	0	1983	1992	−4.5012**	1
26	Slovakia	1992	1996	−0.5871	0	1990	2001	−4.4107**	0
27	Spain	1988	2005	−1.8395	1	1980	2006	−4.2686**	0
28	Sweden	1982	1988	−3.2383	0	1981	1988	−5.5374*	0
29	Switzerland	1980	1999	−3.6544***	4	1985	1999	−5.0293*	4
30	Turkey	1978	1985	−2.1391	0	1983	1998	−3.8234***	3
31	United Kingdom	1978	1985	−3.1929	0	1986	1999	−4.5403**	0
32	Iran	1973	1996	−1.9824	0	1977	1990	−5.0613*	0
33	Algeria	1981	2004	−3.1528	0	1977	1982	−5.4547*	1
34	Egypt	1980	2004	−1.6854	0	1977	2003	−6.2653*	3
35	South Africa	1983	1987	−2.0598	1	1979	1989	−6.1917*	3
36	Australia	2000	2006	−1.5282	2	1988	2004	−6.8117*	3
37	Bangladesh	1976	1982	−4.6667**	0	1974	1987	−5.3723*	2
38	China	1974	2003	−4.0092***	1	1992	2002	−6.8534*	1
39	India	1986	2003	−2.2289	0	1974	1997	−3.4163	0
40	Indonesia	1975	1985	−1.0233	0	1983	1995	−5.4503*	4
41	Japan	1974	1978	−3.9373***	0	1974	1979	−4.1600**	0
42	New Zeeland	2000	2005	−2.1507	0	1983	2001	−6.3277*	3
43	Pakistan	1979	2006	−2.3003	3	1980	1994	−4.8294*	3
44	South Korea	1975	1981	−3.2169	3	1978	1995	−5.0504*	4
45	Taiwan	1983	1991	−1.9635	3	1981	1994	−4.9167*	3
46	Thailand	1978	1984	−1.8153	0	1976	1991	−4.8019*	3
47	Vietnam	2002	2006	−4.0137**	3	1980	1996	−3.8040***	3

Note: This table presents results for univariate LM unit root test with two structural breaks in intercept/constant and trend both. T_{B1} and T_{B2} are the dates of the structural breaks; *k* is the lag length that is the optimal number of lagged first differenced terms included in the unit root test to correct for serial correlation. The 1%, 5% and 10% critical values for the minimum LM test with two breaks are −4.545, −3.842 and −3.504, respectively.

* Denote statistical significance at the 10% level.
** Denote statistical significance at the 5% level.
*** Denote statistical significance at the 1% level.

It is evident from Table 3 that null hypothesis of unit root is rejected (at 10% level of significance) for 11 countries out of 47 countries analyzed when two structural breaks are incorporated in level shift. Further, when we incorporate two structural breaks in level as well as trend, we are able to reject the null hypothesis of unit root for 45 countries out of 47 countries analyzed. The two countries for which null hypothesis of unit root was not rejected are India and Italy.

4. Conclusion and future research

We have examined the stationary properties of coal consumption for 47 developed and developing countries by using (time series data) annual data over 1965–2010. LM unit root test with one break and two break Crash model and one and two break trend models have been utilized. Our empirical results of the unit root test with one break model (more appropriate model of trend break) show that for 27 countries out of 47 countries, the null hypothesis of unit root was rejected at 10% level significance level. Results have seen dramatic change when we have analyzed trend break model while incorporating two structural breaks in the data. Results of trend break model with two breaks show that there are only two countries (namely, India and Italy) for which null hypothesis of unit root was not rejected. Hence, on the basis of empirical evidences investigated in this paper, we can say that coal consumption is stationary in almost all the countries analyzed. Thus, if the coal consumption is mean (or trend) reverting, then it

follows that the series will return to its mean value (or trend path) and it might be possible to forecast future movements in the coal consumption based on past behaviors of the series.

Although our findings indicate that it is not necessary to pay attention to coal consumption excepting for Indian and Italian. But in general, developing economies should explore renewable energy sources for consistent supply of energy to sustain economic growth in long run. The main reason is that non-renewable energy sources have been gradually drying up because of its extensive usages as compared to speed its restoration within earth. On one hand, although, fossil is worthy source of energy, on the other hand, its environmental consequences cannot be ruled out since it also causes large amount of greenhouse emission following its extensive utilization, thus poses serious threats to global warming phenomenon. Given the diminishing nature of non-renewable energy source, interest in renewable energy sources and efficiency has recently grown tremendously. There are significant opportunities exist for the utilization of renewable energy resources worldwide in contrast to other energy resources available, though mostly concentrated to limited numbers of geographical locations. Rapid exploitation of renewable energy and technological diversification of energy sources can cause potential energy security and thus economic benefits. Retrospectively, increasing levels of investment interventions from financial sectors serve as an indicator that sustainable energy has anchored a mainstream role and future of energy production. Few plausibility's could be noted for this increase quest in renewable energy; this include concerns of environmental degradation, combined with surge in oil prices and nuclear hazard and radioactive waste in wake of extensive utilization of non-renewable energy sources.

For the researchers, it is important to take into account the stationarity property of coal consumption and also structural breaks (should be modeled) in their future studies. We have limited ourselves to up to two structural breaks however; there might be evidence of more than two structural breaks for an economy. Therefore, unit root tests that incorporate more than one structural break might give some new results.

References

[1] International Energy Agency (IEA, 2012).

[2] Shahbaz M, Afza T, Zeshan M. Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests Econ Modell 2012;29:2310–9.

[3] Zeshan M, Ahmad V. Energy consumption and economic growth in Pakistan. Bull Energy Econ 2013;1:8–20.

[4] Smyth R. Are fluctuations in energy variables permanent or transitory? A survey of the literature on the integration properties of energy consumption and production Appl Energy 2013;104:371–8.

[5] Apergis N, Loomis D, Payne JE. Are fluctuations in coal consumption transitory or permanent? Evidence from a panel of US states Appl Energy 2010;87: 2424–6.

[6] Im KS, Lee J, Tieslau M. Panel LM unit root tests with level shifts. Oxford Bull Econ Statist 2005;67:393–419.

[7] Westerlund J. New simple tests for panel cointegration. Econ Rev 2005;24 (3):297–316.

[8] Carrion-i-Silvestre J, Barrio-Castro TD. Lopez-Bazo EBreaking the panels: an application of to GDP per capita. Econ J 2005;8:159–75.

[9] Lee J, Strazicich MC. Minimum Lagrange multiplier unit root test with two structural breaks. Rev Econ Statist 2003;85:1082–9.

[10] Lee, J, Strazicich, MC. Minimum LM unit root test with one structural break. Working papers 04–17; 2004. Department of Economics, Appalachian State University.

[11] Narayan PK, Smyth R. Electricity consumption, employment and real income in Australia: evidence from multivariate Granger causality tests. Energy Policy 2005;33:1109–16.

[12] Al-Iriani MA. Energy–GDP relationship revisited: an example from GCC countries using panel causality. Energy Policy 2006;34:3342–50.

[13] Soytas U, Sari R. Can China contribute more to the fight against global warming? J Policy Modell 2006;28 (837-198).

[14] Zachariadis T, Pashourtidou N. An empirical analysis of electricity consumption in Cyprus. Energy Econ 2007;29:183–98.

[15] Narayan PK, Smyth R. Are shocks to energy consumption permanent or transitory? Evidence from 182 countries Energy Policy 2007;35:333–41.

[16] Chen PF, Lee CC. Is energy consumption per capita broken stationary? New evidence from regional-based panels Energy Policy 2007;35:3526–40.

[17] Narayan PK, Narayan S, Smyth R. Are oil shocks permanent or temporary? Panel data evidence from crude oil and NGL production in 60 countries Energy Econ 2008;30:919–36.

[18] Hsu YC, Lee CC, Lee CC. Revisited: are shocks to energy consumption permanent or transitory? New evidence from a panel SURADF approach Energy Econ 2008;30:2314–30.

[19] Mishra V, Sharma S, Smyth R. Are fluctuations in energy consumption per capita transitory? Evidence from a panel of pacific island countries Energy Policy 2009;37:2318–26.

[20] Narayan PK, Narayan S, Popp S. Energy consumption at the state level: the unit root null hypothesis from Australia. Appl Energy 2010;85:1082–9.

[21] Ozturk I, Aslan A. Are fluctuations in energy consumption per capita transitory? Evidence from Turkey Energy Explor Exploit 2011;29:161–8.

[22] Kum H. Are fluctuations in energy consumption transitory or permanent? Evidence from a panel of East Asian & Pacific countries Int J Energy Econ Policy 2012;2(3):92–6.

[23] Kula F, Aslan A, Ozturk I. Is per capita electricity consumption stationary? Time series evidence from OECD countries Renewable Sustainable Energy Rev 2012;16:501–3.

[24] Apergis N, Tsoumas C. Long memory and disaggregated energy consumption: evidence from fossil fuels, coal and electricity retail in the US. Energy Econ 2012;34:1082–7.

[25] Maslyuk, S, Dharmaratna, D. Impact of shocks on Australian coal mining. Department of Economics. Monash University Discussion Paper; 2012. No. 37/12.

[26] Clemente J, Montañés A, Reyes M. Testing for a unit root in variables with a double change in the mean. Econ Lett 1998;59(2):175–82.

[27] Congregado E, Golpe AA, Carmano M. Looking for hysteresis in coal consumption in the US. Renewable Sustainable Energy Rev 2012;16:3339–43.

[28] Shahbaz M, Tiwari AK, Ozturk I, Farooq A. Are fluctuations in electricity consumption per capita transitory? Evidence from developed and developing economies Renewable Sustainable Energy Rev 2013;28:551–4.

[29] Leam HH, Smyth R. Are shocks to disaggregated energy consumption in Malaysia permanent or temporary? Evidence from LM unit root tests with structural breaks Renewable Sustainable Energy Rev 2014;31:319–28.

[30] Bolat S, Belke M, Kovaci S. The stationarity of electricty consumption in selcted European countries. Eur Sci J 2013;19:79–87.

[31] Bolat S, Belke M, Celik N. Mean reverting behavior of energy consumption: evidence from selected MENA countries. Int J Energy Econ Policy 2013;4: 315–20.

[32] Barros CP, Gil-Alana LA, Payne JE. Evidence of long memory behavior in U.S. nuclear electricity net generation. Energy Syst 2013;4:99–107.

[33] Meng M, Payne JE, Lee J. Convergence in per capita energy use among OECD countries. Energy Econ 2012;36:536–45.

[34] Barros CP, Gil-Alana LA, Payne JE. U.S. disaggregated renewable energy consumption: persistence and long memory behavior. Energy Econ 2013;40: 425–32.

[35] Ozcan B. Are shocks to energy consumption permanent or temporary? The case of Turkey Energy Explor Exploit 2013;31:589–606.

[36] Dickey DA, Fuller WA. Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 1979;74:427–31.

[37] Phillips P, Perron P. Testing for a unit root in time series regression. Biometrica 1988;75:333–46.

[38] Ng S, Perron P. Lag length selection and the construction of unit root tests with good size and power,. Econometrica 2001;69:1519–54.

[39] Perron P. Testing for a unit root in a time series with a changing mean. J Bus Econ Stat 1990;8:153–62.

[40] Zivot E, Andrews D. Further evidence on the great crash, the oil price shock, and the unit root hypothesis. J Bus Econ Stat 1992;10:936–54.

[41] Lumsdaine RL, Papel DH. Multiple trend breaks and the unit root hypothesis. Rev Econ Stat 1997;79:212–8.

[42] Im KS, Lee J, Tieslau M. Panel LM unit-root tests with level shifts. Oxford Bull Econ Stat 2005;67:393–419.